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Work Unit Directive (WUD) 56

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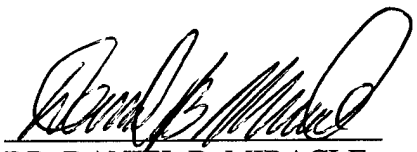

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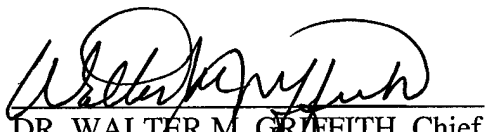

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Books

1. *Intermetallic Matrix Composites*, (eds. D.L. Anton, P.L. Martin, D.B. Miracle, and R. McMeeking), MRS Symp. Proc. **194**, Pittsburgh, PA, (1990)
2. *Intermetallic Matrix Composites II*, (eds. D.B. Miracle, D.L. Anton, and J.A. Graves), MRS Symp. Proc. **273**, Pittsburgh, PA, (1992)
3. *Structural Intermetallics*, (eds. R. Darolia, J.J. Lewandowski, C.T. Liu, P.L. Martin, D.B. Miracle, and M.V. Nathal), Proceedings of 1st International Symposium on Structural Intermetallics, Seven Springs, PA (1993)
4. *Structural Intermetallics 1997*, (eds. M.V. Nathal, R. Darolia, C.T. Liu, P.L. Martin, D.B. Miracle, R. Wagner, and M. Yamaguchi), Proceedings of 2nd International Symposium on Structural Intermetallics, Seven Springs, PA (1997)

Book Chapters

1. D.B. Miracle and R. Darolia; "Structural Applications of NiAl", in *Intermetallic Compounds: Principles and Practice*, (eds. J. H. Westbrook and R. L. Fleischer), John Wiley and Sons, New York, NY, pp 53-72 (1994)
2. D.B. Miracle and M. Mendiratta; "Intermetallic Composites", in *Intermetallic Compounds: Principles and Practice*, (eds. J. H. Westbrook and R. L. Fleischer), John Wiley and Sons, New York, NY, pp 287-300 (1994)

Refereed Publications

1. P.R. Subramanian, D.B. Miracle, and S. Mazdiyasni; "Phase Relationships in the Al-Ta System", *Metall. Trans.*, **21A**, pp 539-545 (1990)
2. S. Mazdiyasni and D.B. Miracle; "Survey of Eutectic Systems as Potential Intermetallic Matrix Composites for High Temperature Application", in *Intermetallic Matrix Composites*, (eds. D. L. Anton, P. Martin, D. B. Miracle, and R. McMeeking), MRS Symp. Proc. **194**, Pittsburgh, PA, pp 155-162 (1990)
3. P.R. Subramanian, D.B. Miracle, M.G. Mendiratta, and D.M. Dimiduk; "NiAl-Mo In-Situ Eutectic Composites", in *Intermetallic Matrix Composites*, (eds. D. L. Anton, P. Martin, D. B. Miracle, and R. McMeeking), MRS Symp. Proc. **194**, Pittsburgh, PA, pp 147-154 (1990)
4. D.K. Patrick, K-M Chang, D.B. Miracle, and H.A. Lipsitt; "Burgers Vector Transition in Fe-Al-Ni Alloys", in *High Temperature Ordered Intermetallic Alloys IV*, (eds. L. Johnson, J. O. Stiegler, and D. P. Pope), MRS Proceedings, **213**, Pittsburgh, PA, pp 267-272 (1991)
5. D. Farkas, R. Pasianot, E.J. Savino, and D.B. Miracle; "Comparison of TEM Observation With Dislocation Core Structure Calculations in B2 Ordered Compounds", in *High Temperature Ordered Intermetallic Alloys IV*, (eds. L. Johnson, J. O. Stiegler, and D. P. Pope), MRS Proceedings, **213**, Pittsburgh, PA, pp 223-228 (1991)
6. D.B. Miracle; "Deformation in NiAl Bicrystals", *Acta Metall. Mater.*, **39**, pp 1457-1468 (1991)

7. D. Dimiduk, D.B. Miracle, Y-W. Kim, and M. Mendiratta; "Recent Progress on Intermetallic Alloys for Advanced Aerospace Systems", *ISIJ International*, **31**, pp 1223-1234 (1991)

8. D. Dimiduk, D.B. Miracle, and C. Ward; "Development of Intermetallic Materials for Aerospace Systems", *Material Sci. Tech.*, **8**, pp 367-375, (1992)

9. M.J. Mills, M.S. Daw, S.M. Foiles, and D.B. Miracle; "HRTEM Observation and EAM Calculation of Dislocation Cores in NiAl", in *High Temperature Ordered Intermetallic Alloys V*, (eds. I. Baker, J. D. Whittenberger, M. Yoo, and R. Darolia), MRS Proceedings, **288**, Pittsburgh, PA, pp 257-262 (1993)

10. P. Hazzledine, K.S. Kumar, and D.B. Miracle; "Syncroshear of the Laves Phase Cr_2Hf", in *High Temperature Ordered Intermetallic Alloys V*, (eds. I. Baker, J. D. Whittenberger, M. Yoo, and R. Darolia), MRS Proceedings, **288**, Pittsburgh, PA, pp 591-596 (1993)

11. M.J. Mills and D.B. Miracle; "The Structure of a<100> and a<110> Dislocation Cores in NiAl", *Acta Metall. Mater.*, **41**, pp. 85-95 (1993)

12. D.B. Miracle; "Overview No. 104: The Physical and Mechanical Properties of NiAl", *Acta Metall. Mater.*, **41**, pp. 649-684 (1993)

13. S. Krishnamurthy, P.R. Smith, and D.B. Miracle; "Preliminary Evaluation of a Ti-24.5Al-17Nb/SiC Composite", *Scripta Metall. Mater.*, **31**, pp 653-658 (1994)

14. M.C. Waterbury, P. Karpur, T.E. Matikas, S. Krishnamurthy, and D.B. Miracle; "In-Situ Observation of the Single-Fiber Fragmentation Process in Metal-Matrix Composites by Ultrasonic Imaging", *Compos. Sci. Tech.*, **52**, pp 261-266 (1994)

15. K.S. Kumar and D.B. Miracle; "Microstructural Evolution and Mechanical Properties of a Cr-Cr_2Hf Intermetallic Alloy", *Intermetallics*, **2**, pp 257-274 (1994)

16. P.R. Subramanian, M.G. Mendiratta, and D.B. Miracle; "Microstructures and Mechanical Behavior of NiAl-Mo and NiAl-Mo-Ti Two-Phase Alloys", *Metall. Trans.*, **25A**, pp 2769-2781 (1994)

17. D.B. Miracle, P.R. Smith, and J.A. Graves; "A Review of the Status and Developmental Issues for Continuously-Reinforced Ti-Aluminide Composites for Structural Applications", in *Intermetallic Matrix Composites III*, (eds. J. A. Graves, R. Bowman, and J. J. Lewandowski), MRS Proceedings, **350**, Pittsburgh, PA, pp 133-142 (1994)

18. K.S. Ravichandran, D.B. Miracle, and M.G. Mendiratta; "Fracture Toughness of Two Cr_2Hf+Cr Intermetallic Composites as a Function of Temperature", in *Intermetallic Matrix Composites III*, (eds. J. A. Graves, R. Bowman, and J. J. Lewandowski), MRS Proceedings, **350**, Pittsburgh, PA, pp 249-254 (1994)

19. S.M. Pickard and D.B. Miracle; "An Experimental Study of Residual Stresses in SiC Fiber-Reinforced Ti-Based Composites", *Mat. Sci. Eng. A*, **205**, pp. 59–68 (1995)

20. S. Krishnamurthy, T.E. Matikas, P. Karpur, and D.B. Miracle; "Ultrasonic Evaluation of the Processing of Fiber-Reinforced Metal Matrix Composites", *Composite Sci. Tech.*, 54, pp. 161–168 (1995)

21. B.S. Majumdar, C. Boehlert, A.K. Rai, and D.B. Miracle; "Structure-Property Relationships and Deformation Mechanisms in an Orthorhombic Based Ti-25Al-17Nb Alloy", in *High Temperature Ordered Intermetallic Alloys VI*, (eds. J.A. Horton, I. Baker, S. Hanada, R.D. Noebe, and D.S. Schwartz), MRS Proceedings, **364**, Pittsburgh, PA, pp 1259-1264 (1995)

22. M.J. Mills, M.S. Daw, J.E. Angelo, and D.B. Miracle; "A Dislocation Model for Flow at Intermediate Temperatures in Hard-Oriented NiAl", in *High Temperature Ordered Intermetallic Alloys VI*, (eds. J.A. Horton, I. Baker, S. Hanada, R.D. Noebe, and D.S. Schwartz), MRS Proceedings, **364**, Pittsburgh, PA, pp 401-406 (1995)

23. K.L. Kendig, W.O. Soboyejo, and D.B. Miracle; "Measurement of Residual Stresses in Ti-15-3/SCS-9 Continuously Reinforced Composites Using X-ray Diffraction and a Matrix Etching Technique", *Scripta Metall. Mater.*, **32**, (5), pp. 669-674 (1995)

24. M.A. Foster, P.R. Smith, and D.B. Miracle; "The Effect of Heat Treatment on Tensile and Creep Properties of 'Neat' Ti-22Al-23Nb in the Transverse Orientation", *Scripta Metall. Mater.*, **33**, pp. 975-981 (1995)

25. D.B. Gundel, B.S. Majumdar, and D.B. Miracle; "Evaluation of the Transverse Response of Fiber-Reinforced Composites Using a Cross-Shaped Sample Geometry", *Scripta Metall. Mater.*, **33**, pp. 2057-2065 (1995)

26. D.B. Miracle, F. Scheltens, and P.R. Subramanian; "Crystal Structure Determination of Al_2Ta", *Phil. Mag. B*, **71**, (5), pp. 941-953 (1995)

27. M.J. Mills, J.E. Angelo, M.S. Daw, J.D. Weinberg, and D.B. Miracle; "Fine Structure of a<110> Dislocations and the Mechanical Properties of NiAl in the Hard Orientation", *Mat. Sci. Eng.*, **A192/193**, pp. 134-141 (1995)

28. B. Maruyama, L.L. Shaw, M.C. Waterbury, D.B. Miracle; "Automated Deformation Mapping Applied to MMC's", *Proc. 10th International Conference on Composite Materials*, (eds. A. Poursartip and K. Street), **Vol. II**, ICCM-10 Society, Vancouver, B.C., pp. 75-82 (1995)

29. D.B. Gundel, B.S. Majumdar, and D.B. Miracle, "The Intrinsic Response of Several Single-Fibre SiC/Ti-6Al-4V Composites to Transverse Tension", *Proc. 10th International Conference on Composite Materials*, (eds. A. Poursartip and K. Street), **Vol. II**, ICCM-10 Society, Vancouver, B.C., pp. 703-710 (1995)

30. S. Krishnamurthy, M.R. James, P.R. Smith, and D.B. Miracle; "The Effects of Matrix Microstructure and Texture on Tensile Behavior of an 'Orthorhombic' Ti-Aluminide/SiC Composite", *Proc. 10th International Conference on Composite Materials*, (eds. A. Poursartip and K. Street), **Vol. II**, ICCM-10 Society, Vancouver, B.C., pp. 739-746 (1995)

31. B.S. Majumdar and D.B. Miracle, "Fiber Coatings for a Sapphire/Gamma TiAl MMC Utilizing Ductile and Barrier Metallic Layers", *Proc. 10th International Conference on Composite Materials*, (eds. A. Poursartip and K. Street), **Vol. II**, ICCM-10 Society, Vancouver, B.C., pp. 747-754 (1995)

32. P. Karpur, T.E. Matikas, S. Krishnamurthy, and D.B. Miracle; "Recent Developments in Ultrasonic Methods for Metal Matrix Composites Research," *Proc. 10th International*

Conference on Composite Materials, (eds. A. Poursartip and K. Street), **Vol. V**, ICCM-10 Society, Vancouver, B.C., pp. 479-486 (1995)

33. M.C. Waterbury, D. Tilly, W. Kralik, and D.B. Miracle, "Evaluation of TMC Interface Properties by the Slice Compression Test", *Proc. 10th International Conference on Composite Materials*, (eds. A. Poursartip and K. Street), **Vol. VI**, ICCM-10 Society, Vancouver, B.C., pp. 719-726 (1995)

34. S.M. Pickard, D.B. Miracle, B.S. Majumdar, K. Kendig, L. Rothenflue, and D. Coker; "An Experimental Study of Residual Fiber Strains in Ti-15-3 Continuous Fiber Composites", *Acta Metall. Mater.*, **43**, (8), pp. 3105-3112 (1995)

35. L. Shaw, D. Miracle, and R. Abbaschian; "Microstructure and Mechanical Properties of Metal/Oxide and Metal/Silicide Interfaces", *Acta Metall. Mater.*, **43**, (12), pp. 4267-4279 (1995)

36. L. Shaw and D.B. Miracle; "On the Relationship between Microstructure and Acoustic Emission in Ti-6Al-4V", *J. Mat. Sci.*, **30**, pp. 4286-4298 (1995)

37. B.S. Majumdar and D.B. Miracle; "Interface Measurements and Applications in Fiber-Reinforced MMC's", *J. Key Engineering Materials*, **116,117**, pp. 153-172 (1996)

38. B. Maruyama, L. Shaw, M.C. Waterbury, and D.B. Miracle; "Automated Deformation Mapping in Metal Matrix Composites", *Mat. Sci. Eng. A*, **205**, pp. 101-109 (1996)

39. S.G. Warrier, D.B. Gundel, B.S. Majumdar, and D.B. Miracle; "Stress Distribution in a Transversely Loaded Cross-Shaped Single Fiber SCS-6/Ti-6Al-4V Composite", *Scripta Mater.*, **34**, pp. 293-299 (1996)

40. K.S. Ravichandran, D.B. Miracle, and M.G. Mendiratta; "Microstructure and Mechanical Behavior of Cr–Cr_2Hf In Situ Intermetallic Composites", *Metall. and Mater. Trans.*, **27A**, pp. 2583–2592 (1996)

41. A.B. Pandey, B.S. Majumdar, and D.B. Miracle, "The Fracture Behavior of SiC_p/Aluminum Alloy Composites With and Without Large Al-Particles," in *Layered Materials for Structural Applications*, (eds. J.J. Lewandowski, C.H. Ward, M.R. Jackson, and W.H. Hunt, Jr.) MRS Proceedings, **434**, Pittsburgh, PA, pp 249–254 (1996)

42. S.G. Warrier, D.B. Gundel, B.S. Majumdar, and D.B. Miracle; "Interface Effects on the Micromechanical Response of a Transversely Loaded Single Fiber SCS-6/Ti-6Al-4V Composite", *Metall. and Mater. Trans* ., **27A**, pp. 2035–2043 (1996)

43. L. Shaw and D.B. Miracle; "Effects of an Interfacial Region on the Transverse Behavior of Metal-Matrix Composites", *Acta Materialia*, **44**, pp 2043–2055 (1996)

44. D.B. Miracle, D.B. Gundel, and S. Warrier; "Interfacial Structure and Properties for the Design of Fiber–Reinforced Metal Matrix Composites", in *Processing and Design Issues in High Temperature Materials*, (eds. N.S. Stoloff and R.H. Jones) TMS, Warrendale, PA, pp 277–286 (1996)

45. A.F. Kalton, D.B. Miracle, and T.W. Clyne; "The Effect of Interfacial Strength on the Response of Ti MMC's to Single Fibre Push–Out and Transverse Tensile Testing". *Key Eng. Mat.*, **127–131**, Part 1, pp. 659–670 (1997)

46. S.G. Warrier, B.S. Majumdar and D.B. Miracle; "Determination of the Interface Failure Mechanism During Transverse Loading of Single Fiber SiC/Ti-6Al-4V Composites From Torsion Tests," *Acta Materialia*, **45**, pp 309–320 (1997)

47. D.B. Gundel, S.G. Warrier, D.B. Miracle, "The Interface Debond Stress in Single and Multiple SiC Fiber/Ti-6Al-4V Composites under Transverse Tension" *Acta Materialia*, **45**, pp 1275-1284 (1997)

48. F. Chu, T.E. Mitchell, B.S. Majumdar, D.B. Miracle, T.K. Nandy and D. Banerjee, "Elastic Properties of the O-Phase in Ti-Al-Nb Alloys," *Intermetallics*, **5**, pp. 147-156 (1997)

49. B.S. Majumdar, T.E. Matikas and D.B. Miracle; "Effects of the Interface on Local vs Global Load Sharing Behavior in Metal Matrix Composites Under Longitudinal Tension", *Proc. 11th International Conference on Composite Materials*, **Vol. III**, (ed. M.L. Scott), Woodhead Publishing, Abington, UK pp 238–249 (1997)

50. D.B. Miracle, A.F. Kalton, and T.W. Clyne; "Transverse Tensile Characterization of SiC/Ti–6242 Fiber–Reinforced MMC's with the Cruciform Sample Geometry", *Proc. 11th International Conference on Composite Materials*, **Vol. III**, (ed. M.L. Scott), Woodhead Publishing, Abington, UK pp 317–326 (1997)

51. S.G. Warrier, B.S. Majumdar, and D.B. Miracle; "Effect of the Interface on Crack Deflection and Fiber Bridging During Fatigue Crack Growth of SiC/Ti-6Al-4V Composites", *Proc. 11th International Conference on Composite Materials*, **Vol. III**, (ed. M.L. Scott), Woodhead Publishing, Abington, UK pp 374–383 (1997)

52. S. Krishnamurthy and D.B. Miracle; "On the Role of C Diffusion During Fiber/Matrix Reaction in SiC Fiber Reinforced Ti-Based MMC's", *Proc. 11th International Conference on Composite Materials*, **Vol. III**, (ed. M.L. Scott), Woodhead Publishing, Abington, UK pp 399–408 (1997)

53. C.J. Boehlert, B.S. Majumdar, S. Krishnamurthy, and D.B. Miracle, "Role of Matrix Microstructure on RT Tensile Properties and Fiber-Strength Utilization of an Orthorhombic Ti-alloy Based Composite", *Metall. and Mater. Trans.*, **28A**, pp 309–323 (1997)

54. S.G. Warrier, B.S. Majumdar, D.B. Gundel and D.B. Miracle, "Implications of Tangential Shear Stress Induced Failure During Transverse Loading of SiC/Ti-6Al-4V Composites," *Acta Materialia*, **45(8)**, pp 3469–3480 (1997)

55. C.J. Boehlert, B.S. Majumdar, V. Seetharaman, D.B. Miracle, and R. Wheeler; "Phase Evolution, Stability, and Microstructure-Creep Relations in an Orthorhombic Ti-23Al-27Nb Alloy", *Structural Intermetallics 1997*, (eds. M.V. Nathal, R. Darolia, C.T. Liu, P.L. Martin, D.B. Miracle, R. Wagner, and M. Yamaguchi), TMS, Warrendale, PA pp. 795–804 (1997)

56. S.G. Warrier, B.S. Majumdar and D.B. Miracle, "Interface Effects on Crack Deflection and Fiber Bridging During Fatigue Crack Growth in Titanium Matrix Composites," *Acta Mater.* **45**, 12, pp 4969-4980 (1997)

57. B.S. Majumdar, S.G. Warrier, and D.B. Miracle: "Interface Effects on the Tensile and FCG Behavior of Fiber–Reinforced Metal Matrix Composites", in *Interfacial Engineering for Optimized Properties*, (eds. C.L. Briant, C.B. Carter, and E.L. Hall), MRS Proceedings **Vol. 458**, Pittsburgh, PA, pp. 185-190 (1997)

58. D.B. Gundel and D.B. Miracle, "The Influence of Interface Structure and Composition on the Response of Single-Fiber SiC/Ti-6Al-4V Composites to Transverse Tension," *Appl. Compos. Mater.*, **5**, pp 95–108 (1998)

59. D.B. Gundel and D.B. Miracle, "The Transverse Tensile Behavior of SiC Fiber/Ti-6Al-4V Composites: Part 1-Experimental Results," *Compos. Sci. Tech.*, **58**, pp. 1571–1581 (1998)

60. A.B. Pandey, B.S. Majumdar and D.B. Miracle; "Effects of Thickness and Precracking on the Fracture Toughness of Particle-Reinforced Al-Alloy Composites", *Metall. Mater. Trans. A*, **29A**, pp 1237-1243 (1998)

61. B.S. Majumdar, T.E. Matikas, and D.B. Miracle; "Experiments and Analysis of Fiber Fragmentation in Single and Multiple Fiber SiC/Ti-6Al-4V Metal Matrix Composites", *J. of Compos. B*, **29B**, pp 131-145 (1998)

62. S. Krishnamurthy, P.R. Smith, and D.B. Miracle; "Modification of Transverse Creep Behavior of an Orthorhomibic Titanium Aluminide Based Ti-22Al-23Nb/SiCf Composite Using Heat Treatment", *Mat. Sci. Eng.*, **A243**, pp. 285-289 (1998)

63. S.G. Warrier, B. Maruyama, B.S. Majumdar and D.B. Miracle; "Behavior of Several Interfaces During Fatigue Crack Growth in SiC/Ti-6Al-4V Composites", *Mat. Sci. Eng.*, **A259**, pp 189-200 (1999)

64. A.B. Pandey, B.S. Majumdar and D.B. Miracle; "Effect of aluminum particles on the fracture toughness of a 7093/SiC/15p composite", *Mat. Sci. Eng.*, **A259**, pp 296-307 (1999)

65. D.B. Miracle and B.S. Majumdar; "Transverse Creep of SiC/Ti-6Al-4V Fiber-Reinforced MMC's", *Metall. Mater. Trans. A*, **30A**, pp 301-306 (1999)

66. C.J. Boehlert, B.S. Majumdar, V. Seetharaman and D.B. Miracle; "Part I. The Microstructural Evolution in Ti-Al-Nb O + Bcc Orthorhombic Alloys", *Metall. Mater. Trans. A*, **30A**, pp 2305–2323 (1999)

67. C.J. Boehlert and D.B. Miracle; "Part II. The Creep Behavior of Ti-Al-Nb O+bcc Orthorhombic Alloys", *Metall. Mater. Trans. A*, **30A**, pp. 2349–2367 (1999)

68. D.B. Gundel, S.G. Warrier, D.B. Miracle "The Transverse Tensile Behavior of SiC Fiber/Ti-6Al-4V Composites: 2 - Stress Distribution and Interface Failure," *Compos. Sci. Tech.*, **59**, pp. 1087-1096 (1999)

Non-Refereed Publications

1. D.B. Miracle; *The Deformation of NiAl Bicrystals*, WL–TR-92-4111, Wright-Patterson AFB, OH (1992)

2. S. Krishnamurthy, P.R. Smith, and D.B. Miracle; "Preliminary Study of a Ti-24.5Al-17Nb/SCS–6 Composite", *Titanium Metal Matrix Composites II*, (eds. P. R. Smith and W.C. Revelos), WL–TR–93–4105, Wright–Patterson AFB, OH pp 59–75 (1993)

3. Roman, S. Krishnamurthy, and D.B. Miracle; "Fiber-Matrix Interfacial Behavior in SiC-Titanium Alloy Composites", in *Titanium '92- Science and Technology*, (eds. F. H. Froes and I. Caplan), Proc. Seventh World Conf. on Ti, pp 2545-2551 (1993)

4. M.J. Mills, D.C. Chrzan and D.B. Miracle; "Influence of Dislocation Fine Structure on the Strength and Flow Behavior of Ordered Intermetallic Compounds," *Proceedings of the*

10th International Conference on the Strength of Materials, ICSMA-10, (eds. H. Oikawa, K. Maruyama, S. Takeuchi and M. Yamaguchi), Japan Institute of Metals, pp. 41-48 (1994)

5. B.S. Majumdar, C.J. Boehlert, and D.B. Miracle; "Deformation Mechanisms and Structure-Property Relations in O-Alloys and MMC's (Ti-25Al-17Nb System)", *Orthorhombic Titanium Matrix Composites*, (ed. P. R. Smith), WL–TR–95–4068, Wright–Patterson AFB, OH pp 64–82 (1995)

6. S. Krishnamurthy, P.R. Smith, and D.B. Miracle; "Microstructure and Properties of 'Neat' and SCS-6 Reinforced Ti-24.5Al-17Nb (1Mo) Composite Materials", *Orthorhombic Titanium Matrix Composites*, (ed. P. R. Smith), WL–TR–95–4068, Wright–Patterson AFB, OH pp 83–104 (1995)

7. L. Shaw and D.B. Miracle; "Microscopic Damage of Ti-6Al-4V/SiC Composites Under Transverse Loading Conditions", in *Light-Weight Alloys for Aerospace Applications III*, (eds. E.W. Lee, N.J. Kim, K.V. Jata, and W.E. Frazier), TMS, Warrendale, PA, pp 379–390 (1995)

8. C.J. Boehlert, B.S. Majumdar, and D.B. Miracle; "Effects of Microstructure on the Tension, Fatigue Crack Growth, and Creep Behavior of a Ti-25Al-17Nb Alloy", *Fatigue and Fracture of Ordered Intermetallics II*, (eds. T. Srivatsan, W.O. Soboyejo, and R.O. Ritchie), TMS, Warrendale, PA, pp 135-153 (1995)

9. D.B. Miracle, M.A. Foster, and C.G. Rhodes; "Phase Equilibria in Ti–Al–Nb Orthorhombic Alloys", in *Titanium '95–Science and Technology*, (eds. P.A. Blenkinsop, W.J. Evans, and H.M. Flower), Proc. Eighth World Conf. on Ti, University Press, Cambridge, UK, pp 372–379 (1996)

10. Pandey, B.S. Majumdar, and D.B. Miracle, "Processing and Fracture Behavior of SiC/Al Alloy Composites," in *Processing and Fabrication of Advanced Materials V*, (eds. T.S. Srivatsan and J.J. Moore), TMS, Warrendale, PA, pp 185-198 (1996)

11. K.L. Kendig, R. Gibala, B.S. Majumdar, D.B. Miracle, and S.G. Warrier; "Nanoindentation as a Probe for Residual Stress," *Light Weight Alloys for Aerospace Applications IV*, TMS, Warrendale, PA, pp. 299-310, (1997)

12. D.B. Gundel and D.B. Miracle; "The Influence of Interface Structure and Composition on the Response of Single-Fiber SiC/Ti-6Al-4V Composites to Transverse Tension", in *Orthorhombic Titanium Matrix Composites II*, (ed. P. R. Smith), WL–TR–97–4082, Wright–Patterson AFB, OH pp 34–46 (1997)

13. D.B. Gundel and D.B. Miracle; "Effect of the Interface on Crack Deflection and Fiber Bridging During Fatigue Crack Growth of SiC/Ti-6Al-4V Composites", in *Orthorhombic Titanium Matrix Composites II*, (ed. P. R. Smith), WL–TR–97–4082, Wright–Patterson AFB, OH pp 73–82 (1997)

14. C.J. Boehlert, B.S. Majumdar, V. Seetheraman and D.B. Miracle; "The Phase Evolution, Tensile and Creep Behavior of Near Stoichiometric Ti_2AlNb Orthorhombic Alloys", in *Orthorhombic Titanium Matrix Composites II*, (ed. P. R. Smith), WL–TR–97–4082, Wright–Patterson AFB, OH pp 212–227 (1997)

Invited Presentations and Colloquia

1. "On the Mechanism of Ductility in NiAl", TMS Spring Meeting, Anaheim, CA, 21 Feb 1990
2. "Metallic Composites", University Research Initiative Winter Study Group, Santa Barbara, CA, 8 Jan 1991
3. "Metallic Composites for High Temperature Structural Materials", Virginia Polytech, Blacksburg, VA, 22 Mar 1991
4. "High Temperature Structural Aerospace Materials", Cornell University, Ithaca, NY, 5 Apr 1991
5. "Deformation in Advanced Metallic Composites", Office Nationale d'Etude et Recherche Aerospatiale (ONERA), Paris, France, 8 Jul 1991
6. "Deformation and Atomic Resolution Microscopy in NiAl Bicrystals", General Electric Corporate Research and Development Center, Schenectady, NY, 2 Dec 1991
7. "Research in Advanced Metallic Composites", General Electric Corporate Research and Development Center, Schenectady, NY, 3 Dec 1991
8. "High Temperature Structural Aerospace Materials", Cleveland Chapter of ASM, Cleveland, OH, 4 May 1992
9. "The Influence of Matrix Deformation on Tensile Behavior in Continuously-Reinforced MMC's", International Conference on Composite Materials IX, Madrid, Spain, 14 Jul 1993
10. "Fiber Fragmentation in Continuously-Reinforced Ti-Based MMC's", Cambridge University, Cambridge, England, 19 Jul 1993
11. "Structural Applications of NiAl", Structural Intermetallics: Perspectives on Science and Technology, Defence Metallurgical Research Laboratory, Hyderabad, India, 5 Feb 1994
12. "Ti-Alloy Metal Matrix Composites for Aerospace Applications", MRS of India Annual Meeting, Defence Research and Development Laboratory, Hyderabad, India, 6 Feb 1994
13. "Interface Properties in Continuously-Reinforced Ti-Based MMC's", The Metallurgical Society Annual Meeting, San Francisco, CA 1 Mar 1994
14. "A Review of the Status and Developmental Issues for Continuously-Reinforced Ti-Aluminide Composites for Structural Applications", MRS Spring Meeting, San Francisco, CA, 5 Apr 1994
15. "An Experimental Study of Residual Fiber Strains in Ti-15-3 Continuous Fiber Composites", Carnegie Mellon University, Pittsburgh, PA, 19 Apr 1994
16. "Fundamental Aspects of Continuously-Reinforced MMC's", with B. Maruyama and D. Gundel, MMC Information and Analysis Center, Salt Lake City, UT, 8 Feb 1995
17. "Research and Development of Aerospace Materials," Tau Beta Pi Induction Ceremony, Wright State University, Dayton, OH, 10 Mar 1995
18. "Development and Technology Transition of Fibre-Reinforced MMC's for Aerospace Applications", Department of Materials Science and Metallurgy, Cambridge University, Cambridge, UK, 16 Oct 1995

19. "Transverse Interface Properties in Fibre–Reinforced MMC's Using a Cruciform Sample Geometry", Department of Materials Science, Oxford University, Oxford, UK, 30 Oct 1995
20. "Interface Properties in Continuously–Reinforced Ti-MMC's", Department of Materials Science, University de Leuvan, Leuvan-le-Neuve, Belgium, 4 Mar 1996
21. "Transverse Characterization of Ti-6Al-4V/SiC Composites", Max–Planck Institute, Stuttgart, Germany, 2 Apr 1996
22. "Transverse Interface Properties in Fibre–Reinforced MMC's Using a Cruciform Sample Geometry", Department of Materials Science, Imperial College, London, UK, 18 Jun 1996
23. "Relationships Between Interface Properties and Composite Properties in Ti-Based MMC's", Department of Materials Science, University of Birmingham, Birmingham, UK, 5 Jul 1996
24. "Metallic Composites," AFOSR Contractor's Meeting, Bar Harbor, ME, 22 Aug 1996.
25. "Interfaces in SiC/Ti MMC's and Their Influence on Properties", College of Engineering and Applied Science, University of Colorado, Boulder, CO, 20 Mar 1997
26. "Interface Development for Titanium Matrix Composites", AeroMat, Williamsburg, VA, 14 May 1997
27. "Study and Development of Interfaces in Titanium Matrix Composites", Department of Materials Science and Engineering, University of Cincinnati, Cincinnati, OH, 23 May 1997
28. "Transverse Tension and Creep of SiC/Ti-Alloy MMC's", TMS Fall Meeting, Indianapolis, IN, 16 Sep 1997
29. "Relationships Between Interface Properties and Composite Properties", National Science Foundation/Institute for Mechanics and Materials Workshop on Composite Materials, Mescalero, NM, 7 Oct 1997